# How Do Biological Systems Originate?

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Evidence that bears on the origin and early history of life falls into two general categories: physical and genetic. Physical information relevant to early life includes hard fossils, as well as chemical remnants and isotopic signatures of past biochemistry. Genetic information, read in the gene sequences of contemporary organisms, also reveals fossil remnants of ancient genes. Paths of evolution are traced using the techniques of molecular phylogeny, comparison of gene sequences to infer relationships and properties of organisms, present and past. The molecular view of the nature and history of life can be relatively objective, but it also is a young and poorly developed arena. Nonetheless, significant truths have emerged, some that invalidate traditional beliefs.

Large-scale genetic relationships usually are expressed as phylogenetic trees. The outlines of a universal phylogenetic tree have emerged with comparisons of ribosomal RNA sequences, which trace the evolution of the genetic machinery. The molecular trees can recover biological events that the physical record will not be able to address, for instance the importance of gene transfers between cellular lineages. Not all genes track with the rRNA genes evolutionarily. Some genes have been transferred, laterally, between different lines of descent as outlined by rRNA and other elements of the genetic machinery. Such lateral transfers are relatively rare and idiosyncratic, but nonetheless some have powerfully steered the course of evolution, for instance in the development of oxygen production by cyanobacteria. Early in evolution, before the development of independent cellular lineages, it is likely that gene transfers between replicating foci were frequent. The genetic code was, and remains, the universal language.